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Using a General Indexing Paradigm to Monitor Rodent Populations

Population monitoring is a valuable component to managing invasive rodent populations. Indices can be efficient methods for monitoring rodent populations when more labor intensive density estimation procedures are impractical or invalid to apply, and many monitoring objectives can be couched in an indexing framework. Indexing procedures obtain maximal utility if they exhibit key characteristics, including being practical to apply, being sensitive to changes or differences in the target species= population, having an inherent variance formula and allowing for precision in index values, and relying on as few assumptions as possible. Here, a general indexing paradigm that promotes the characteristics that make indices most useful is specifically applied for rodent monitoring scenarios. Observations are made at stations located throughout the area of interest. Stations can take many forms, depending on the observations, and range from points for visual counts to tracking plots (or tiles), bait blocks, chew cards, trap lines and many others. A wide variety of observation methods for many animal species can fit into this format. Observations are made at each station on multiple occasions for each indexing session. Geographic location data for each station are encouraged to be collected. No assumptions of independence are made among stations, nor among observation occasions. Measurements made at each station are required to be continuous or unboundedly discrete. The formula for a general index to describe population levels is presented along with a derived variance formula. Issues relevant to the application of this methodology to rodent populations, and indices in general, are discussed.

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EPA's Comparative Risk Assessment for Nine Rodenticides

As part of the reregistration of pesticides mandated by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), U.S. EPA's Office of Pesticide Programs (OPP) conducted a comparative risk assessment for nine rodenticides that pose potential risks to birds and nontarget mammals. The rodenticides include 3 second-generation anticoagulants (brodifacoum, difethialone, bromadiolone), 3 first-generation anticoagulants (diphacinone, chlorophacinone, warfarin), and 3 non-anticoagulant compounds (zinc phosphide, bromethalin, cholecalciferol). These rodenticides are used predominantly to control commensal rats and mice in and around buildings; some also have field uses. Rodenticide food baits are not selective to the target species, and birds and nontarget mammals attracted to grain-based or other food baits are at risk. Information from laboratory and pen studies, field studies and control programs, incident reports, and toxicokinetic studies also indicates that avian and mammalian predators and scavengers can be at risk from consuming target and nontarget animals poisoned with some of these rodenticides. Because exposure and effects data are limited or are not easily expressed in quantitative terms, a lines-of-evidence approach and a comparative analysis model are used to categorize risk rankings for primary risks to birds and nontarget mammals and secondary risks to avian and mammalian predators and scavengers. This approach to evaluating risks complies with EPA's Guidelines for Ecological Risk Assessment.

The highly persistent, single-feeding second-generation anticoagulants stand out as the rodenticides posing the greatest overall risks to nontarget species. More than 250 incidents, mostly with brodifacoum, attest that exposure occurs to owls, hawks, eagles, corvids, foxes (including endangered kit foxes), coyotes, and others. First-generation anticoagulants are less persistent and appear to pose considerably less risk to birds, although primary and secondary risks to mammals exceed the Agency's Levels of Concern. The non-anticoagulants pose primary risks to birds and nontarget mammals; they appear to pose minimal secondary risks, but confirmatory data are needed for bromethalin and cholecalciferol. Risk presumptions are based on a deterministic approach, and many uncertainties exist. Refining the assessment to establish a quantitative measure of likelihood of exposure and effects would require a much more extensive data set than is currently available. Such information includes spatial/temporal data on quantities of bait applied and baiting practices, including use of bait stations and indoor versus outdoor applications for each target species; primary and secondary hazards data for focal species; sublethal effects on behavior and reproduction; diet and foraging behavior of predators and their opportunism in exploiting poisoned rodents and birds; behavior of poisoned rodents; residues in target and nontarget consumers before and after death; and numerous others. Better monitoring and incident reporting also is essential.

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Anticoagulant Residues in Rat Liver: Persistence and Secondary Hazard to Non-target Species

In New Zealand, the second-generation anticoagulant brodifacoum has been successfully used in island rodent eradications and is currently applied in some mainland areas to control introduced pests such as brushtail possums (*Trichosurus vulpecula*) and rodents (*Rattus* spp.). However, ongoing field use of brodifacoum is under scrutiny because nontarget wildlife can acquire persistent residues. To investigate alternative rodenticides, the persistence of sublethal oral doses of five anticoagulants (brodifacoum, warfarin, pindone, diphacinone and coumatetralyl) in laboratory rats was compared. Diphacinone and pindone had the shortest hepatic half-lives, indicating a shorter-term secondary hazard. A further study compared concentrations of liver residues of the five anticoagulants in laboratory rats after different regimes of bait consumption. These data, alongside available toxicity values, were used to construct a theoretical, conservative assessment of the risk of acute secondary poisoning to New Zealand nontarget birds and mammals. Taking account of persistence, acute toxicity and residue concentrations in rats, brodifacoum presented the overall highest secondary risk and diphacinone the overall lowest. However, warfarin presented a very low risk to birds, and medium risk to mammals. Coumatetralyl was the most persistent of the first-generation anticoagulants studied, but a very low risk to birds and medium risk to mammals was indicated. Pindone had a short persistence like diphacinone, but had a high risk to birds and a medium risk to mammals. Diphacinone especially, but also coumatetralyl and warfarin, should be further evaluated in field studies as alternative rodenticides for use in New Zealand.

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An Overview of Rodent-borne Diseases

Interest in rodent-associated zoonotic diseases has increased during recent years as a result of high profile outbreaks involving well-known rodent-associated disease agents (plague and tularemia), the sudden appearance of unexplained illnesses caused by previously unrecognized rodent-associated pathogens (Lyme disease and Hantavirus Pulmonary Syndrome), the introduction of exotic disease agents into native host populations (monkeypox virus in pet prairie dogs and humans), or the fears that some of these agents, especially plague or tularemia, might be used as weapons of bioterrorism. This presentation briefly reviews the status of the above diseases and their etiologic agents. Also discussed are current concerns about their spread and control.

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Probabilistic Risk Assessment Model for Predators and Scavengers Exposed Indirectly to a Rodenticide

A probabilistic model is described for estimating the risk to predators and scavengers from indirect exposure to a rodenticide. The model combines predictions of dietary exposure with information about toxicological effects to estimate the likelihood that an individual predator or scavenger will accumulate a lethal dose. The exposure model is a probabilistic implementation of a standard dietary dose model based on food ingestion rate, percentage rodents in the diet, percentage of rodents that have been exposed to a rodenticide baiting program, and concentration of rodenticide in exposed rodents. Data on some of the model parameters (especially dietary composition and rodenticide concentrations in rodents) are available from field studies, while other parameters are based on expert opinion or assumptions. The model generates exposure probability curves for individuals, and also simulates variability among individuals. Effects of rodenticide exposure are estimated from laboratory studies with birds and mammals. A Bayesian hierarchical approach combines raw data from all studies into calculated dose-response relationships for individual species, or for species of unknown sensitivity. The exposure probability curves and dose-response curves are integrated into curves depicting the likelihood of lethal poisoning of an individual predator or scavenger. The model is illustrated using the coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), red fox (*Vulpes vulpes*), great-horned owl (*Bubo virginianus*), and red-tailed hawk (*Buteo jamaicensis*) as the focal species. Through selection of distributions or assumptions for model parameters, the model can be used to explore a range of exposure scenarios and rodenticide baiting practices.

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Virus-vectored Fertility Control for House Mouse (*Mus domesticus*) in Australia

House mouse populations erupt irregularly in the grain growing regions of south-eastern Australia, reaching densities greater than 1000 mice per hectare and causing major economic impacts within rural communities. Current control strategies usually involve the use of rodenticides (e.g. zinc phosphide), which are not target specific, are costly to apply, can lead to environmental damage and their humaneness is being questioned.

As an alternative to current lethal agents, fertility control approaches whereby viruses are being assessed as delivery vectors are being developed. The research program combines molecular biology, population ecology and epidemiology of the virus vector as well as risk assessment of the use of genetically engineered organisms in the Australian landscape.

An ideal immunocontraceptive vaccine must induce a sustained immune response which blocks a key reproductive process (e.g. ovulation or fertilization), be species-specific, be delivered effectively throughout the pest population on a broad scale, be cost-effective, environmentally benign and publicly acceptable – a big challenge. The components of the fertility control approach for the wild house mouse comprise mouse zona pellucida protein C (mZP3) and mouse cytomegalovirus (MCMV). MCMV has been chosen as the candidate delivery vector for a number of reasons. Importantly the virus is present at high prevalence in wild mice in Australia, and it is species-specific. The virus spreads between mice by close contact, and mice can become infected with multiple strains, which means that super-infection with a recombinant virus is feasible. The virus persists in the salivary gland and lung and can be reactivated during periods of stress (e.g. social interactions). As a DNA virus it can be engineered to carry additional genetic information.

In the laboratory we have successfully tested the effects of infection of mice with an engineered Australian strain of MCMV expressing the mZP3 gene (recMCMV-mZP3). Infection with the recombinant virus results in the stimulation of the host immune system – antibodies to both the virus and mouse ZP3 are produced. The mice are infertile for approximately 250 days. Infertility appears to be due to complete loss of primordial follicles within the ovaries of infected mice indicating that sterility is permanent and irreversible. A major challenge being addressed in current experiments is whether the vaccine transmits between mice and continues to induce infertility.

Field and laboratory results so far, as well as computer modelling, indicate excellent prospects for the use of viral vectored vaccines based on MCMV for managing eruptions of mouse populations. However, the public acceptability of the technology is yet to be confirmed. The issues of species specificity, delivery system stability and other potential or perceived risks require open and wide-ranging debate, nationally and internationally, before trial field experiments of a genetically modified virus for controlling field populations of mammals could occur.

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Island Conservation in the U.S. Channel Islands National Park: Rat Eradication from Anacapa Island

The ability to eradicate rats from islands is one of the most powerful tools available to prevent extinctions. This tool has been underutilized in North America where the relatively few eradications have utilized bait stations alone. On many islands, bait stations alone cannot be used due to steep topography or sensitive species. Anacapa Island (a steep and rugged 296 ha island consisting of three distinct islets) had introduced *Rattus rattus* that threatened native species, including an endemic deer mouse (*Peromyscus maniculatus anacapae*). Consequently, aerial broadcast was the only feasible method to eradicate rats. After 2 years of planning, testing and monitoring, *a* 25 ppm brodifacoum bait was aerially broadcast onto East Anacapa in December 2001, and onto Middle and West Anacapa Island in November 2002. We protected the endemic mouse by staggering the eradication so that a free ranging population always existed on one or more islets. In addition, we maintained a captive population on island followed by a soft release and subsequent monitoring to ensure viability. This was the first aerial application of rodenticide to eradicate rats in North America, and the first on an island with an endemic rodent. The legal and public scrutiny and the complex environmental compliance process required extensive mitigation to minimize primary and secondary risks to birds, and reduce potential bait drift into the marine ecosystem. Hopefully, the success of this project will facilitate future rat eradications in North America.

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A Century of Rodent Control

There has been a long history of development and testing of methods for rodent control, including traps, toxicants, and delivery systems. A wide array of tools and techniques has been available for managing rodents, however, changing social dynamics and the emergence of the animal rights movement have led to increasing restriction or elimination of many of the traditional strategies or materials used by wildlife managers and pest management specialists. This has created a demand for new approaches to rodent damage management. The challenge to wildlife scientists is to provide data to maintain the broadest array of appropriate, science-based techniques and management options, while fostering the rapid development and application of new technology.

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Pesticide Registration Requirements in the U.S. with Emphasis on Options for Controlling Invasive Rodents

This presentation discusses U.S. regulatory options and registration requirements for pesticide products such as might be used to control invasive rodents that threaten the viability of populations of native species. The regulatory options are: a full Federal registration under §3 of the Federal Insecticide Fungicide and Rodenticide Act (FIFRA), a "special local needs" registration under §24(c) of FIFRA to allow use of the pesticide in the State where the problem occurs, an experimental use permit under §5 of FIFRA to authorize research related to the problem at hand, an emergency exemption from some or all of the requirements of FIFRA (as authorized under §18), or a determination under §25(b) of FIFRA that the selected pesticide is of a character such as not to require regulation under FIFRA. The paper discusses the requirements for and the advantages and disadvantages of each of these regulatory options.

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Probabilistic Risk Assessment Model for Determination of Non-target Risks to Birds in Diphacinone Rodenticide Baited Areas on Hawaii

Three probabilistic models were developed for characterizing the risk of mortality and subacute coagulopathy to Po'ouli, an endangered non-target avian species, in broadcast diphacinone baited areas on Hawaii. For single day exposure, the risk of Po'ouli mortality approaches 0. For 5 day exposure, the mean probability of mortality increased to 3% for adult and 6% for juvenile Po'ouli populations. For Po'ouli which consume snails containing diphacinone residues for 14 days, the model predicted increased levels of coagulopathy for 2.4% and 4.0% of adult and juvenile Po'ouli populations, respectively. Worst case deterministic risk characterizations predicted acceptable levels of risk for non-threatened or endangered species such as northern bobwhite quail and mallards.

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Development of Nutria Eradication Strategies for Chesapeake Bay Marshlands

Non-native nutria (*Myocastor coypus*) have been linked to the destruction of more than 8,000 acres of marshlands at the Blackwater Unit of the Chesapeake Marshlands National Wildlife Refuge Complex. Feral populations were first established in the 1940's in Dorchester County, Maryland, and populations have since expanded throughout the Delmarva Peninsula, threatening marsh habitats throughout the Chesapeake Bay watershed. We describe ongoing efforts to eradicate this invasive species from Chesapeake Bay marshlands. Traditional harvest techniques, including trapping and hunting, are being applied within an Integrated Wildlife Damage Management framework in order to achieve a systematic and progressive removal of nutria from discreet units of marsh habitat. To date, 8,000 nutria have been removed from nearly 35,000 acres of marsh habitat at Blackwater Unit and surrounding private marshes. Nearly 92% of trapping units remain nutria free as long as 15 months post removal, indicating that nutria eradication from Chesapeake Bay marshlands may be possible.